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CARDEROCKDIV-PAS-92/40 Automated Ship Auxiliary Systems Design Process--Ship Parametric Modeling Program

**Carderock Division
Naval Surface Warfare Center**

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Bethesda, Maryland 20084-5000



CARDEROCKDIV-PAS-92/40 March 1993

Propulsion and Auxiliary Systems Department
Research and Development Report

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**Automated Ship Auxiliary Systems Design Process --
Ship Parametric Modeling Program**

by
David J. Nordham



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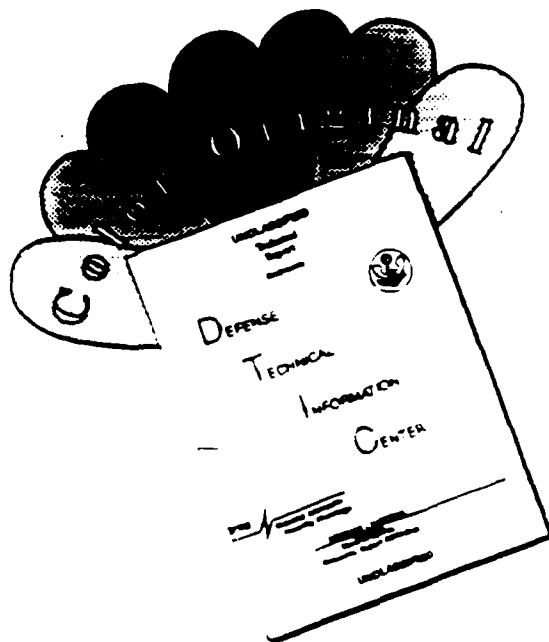
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ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
CAD	Computer-Aided Design
FY	Fiscal Year
NAVSEA	Naval Sea Systems Command
ONR	Office of Naval Research

ABSTRACT

An automated design process is being developed to examine the potential impact of design changes made to a surface ship auxiliary system. This automated design process will uniquely allow the examination of how design changes to an auxiliary system will impact different sized combatants. The design process will be composed of two main programs -- a Ship Parametric Modeling Program in which the ship and auxiliary systems model is developed in a parametric computer program, and a Benefit Analysis Model in which the systems characteristics (e.g., weight, volume, and cost) are calculated for comparison to alternative components and system concepts. This report highlights the work done on the automated design process in FY 1992, specifically the work done on the Ship Parametric Modeling Program.

ADMINISTRATIVE INFORMATION

This report is submitted in partial fulfillment of Milestone 1, Task 3 of the Mechanical Power and Auxiliary Systems Project (RH21E42) of the Surface Ship Technology Block Program (ND1A/PE0602121N). The work described herein was sponsored by the Office of Naval Research (ONR 211) and performed by the Carderock Division, Naval Surface Warfare Center, Annapolis Detachment.

INTRODUCTION

Current auxiliary systems aboard U.S. Navy surface combatants are often designed with redundant paths to maintain a high level of reliability and survivability. A negative result of this type of design, though, is an increase in the weight, volume, and cost of the systems. Future ship requirements are placing an increased emphasis on reducing the weight, volume, and costs of auxiliary systems while maintaining or increasing the reliability and survivability. Previous work^{*} by the Naval Surface Warfare Center,

^{*} Shiffler, Mark E., "Distributed Fire Main System Concept Development and Preliminary Analysis." DTRC-TM-27-91-68 (Dec 1991).

Carderock Division, examined the use of a different approach to the design of auxiliary systems. This different approach, known as distributed architectures, employs the use of zones that can be isolated from the rest of the system without shutting down the entire system. A comparison between the current fire main system on board the DDG-51 and a hypothetical distributed fire main system design revealed that the distributed fire main design had potentially significant savings in the weight (17% savings), volume (8% savings), and cost (28% savings) over the current system.

The results of the investigation into distributed architectures demonstrated the benefits of analyzing different design approaches for auxiliary system architectures. As a result, there exists a need to examine many different designs for an auxiliary system to obtain the most desirable layout in terms of weight, volume, cost, reliability, and survivability. This design process would work best as an automated operation employing high-speed computers for fast analysis and evaluation of the proposed design. An automated design process would allow a ship designer the capability of a quick comparison of several variations of a distributed auxiliary system within a given combatant or the capability of analyzing a new distributed system design in many different combatants. To this end, a 6.2 exploratory development task has been ongoing at the Naval Surface Warfare Center, Carderock Division, to use state-of-the-art Computer-Aided Design (CAD) software and hardware to develop an automated ship auxiliary systems design process.

APPROACH

The automated design process is to be composed of two main programs. The first program is the Ship Parametric Modeling Program. This program utilizes parametric CAD software to model the ship and auxiliary systems. A CAD program is parametric when the dimensions and locations of certain parts of a model can be related, by mathematical equations, to a controlling parameter and have these parts be automatically updated as the controlling parameter value is changed. By using the parametric features of the software, an auxiliary systems model can be created that is related mathematically to ship dimensions and layouts. When a new value is given to a controlling ship dimension, the ship model and associated auxiliary systems model change to reflect the new value. The output of the Ship Parametric Modeling Program is a list of the location and physical characteristics of the auxiliary systems components. Work on this program is being done in fiscal year (FY) 1992.

The second program of the automated design process is the Benefit Analysis Model. This program accepts the components list from the Ship Parametric Modeling Program and calculates system characteristics (e.g., weight, volume, and cost). A report can then be generated for comparison to alternative designs for the auxiliary system. Work on this program will be done in FY 1993.

This report describes the work done in FY 1992 on the automated ship auxiliary systems design process by the Naval Surface Warfare Center, Carderock Division -- specifically the work done on the Ship Parametric Modeling Program.

SHIP PARAMETRIC MODELING PROGRAM

To display the capabilities of the Ship Parametric Modeling Program, a parametric ship and piping system model was created using the DDG-51 and the distributed fire main system as a guide. All work on the parametric modeling program is being done on a UNIX-based workstation and software obtained from the NAVSEA CAD-2 contract.

The first step in this modeling program consists of specifying, by mathematical equations, the location of all points defining the DDG-51 ship model and the distributed fire main system model. All points are defined relative to the model's base coordinate system located at the bow of the ship. Since the locations of all points are described by mathematical equations to some controlling parameters, by changing the value of these controlling parameters or the constants in the equations, these locations can be changed. The controlling parameters for this model are the ship's length, width, and height. A representative list of the mathematical equations defining the parametric points of the ship and piping models is included in Appendix A.

The DDG-51 ship model was created as a wireframe model representing the ship's hull structure, bulkhead, and deck locations. The ship model was developed by connecting the parametric points with lines. All endpoints of the lines were "attached" in the CAD software to the parametric points so that any change in the point's location also changes the location of the line. The ability to automatically change the ship dimensions is displayed in Figures 1 and 2. Figure 1 shows the ship wireframe model with the original dimensions of approximately 505 ft length, 66 ft width, and 36 ft height

and Figure 2 shows the ship wireframe model with the dimensions changed to 400 ft length, 100 ft width, and 50 ft height.

Individual sections of the ship model can also be changed. This allows changes to be made to, or the elimination of, individual bulkhead sections without an adverse effect on other bulkhead sections. Figures 3 and 4 display a change made to the distance between bulkheads 2 and 3 of the ship model. Figure 3 shows the bulkheads at the original distance of 36 ft apart, and Figure 4 shows the bulkheads at a distance of 20 ft apart.

The next step was to model the representation of the distributed fire main system within the ship model. This system was created by locating parametric points at places where the piping system would have bends, tees, valves, fittings, or pumps. With the use of the CAD software's pipe routing program, the parametric points were connected with lines representing the piping centerline. Pipe characteristics can be input in the CAD program. These characteristics include pipe material, nominal pipe diameter, operating and design temperatures and pressures, insulation type and thickness, and fluid carried. The routing program then traverses the drawn centerline and inserts the specified pipe based on given input and dimensions obtained from databases located on the computer system. Bends are automatically put in places where the endpoints of two non-parallel centerlines intersect, and tees are located where the endpoint of one centerline intersects in the middle of a second centerline. Reducers are automatically located where a change in nominal pipe diameters are specified. Valves, flanges, supports, and other fittings are inserted in the piping model by specifying the location

and type of component. Pumps were drawn in a separate CAD model and attached to the piping system by referencing the pump model.

The ship model with the distributed fire main model is shown in Figure 5. Nominal pipe diameters of 2 in. (displayed in green), 4 in. (displayed in blue), and 6 in. (displayed in red) were used in this model. All pipe, fittings, and components are then attached to the corresponding parametric points. As the values for the locations of these parametric points are changed, the locations of the pipe, fittings, and components change accordingly. Figure 5 shows the original model and Figure 6 is a new regenerated model using the same dimensions as Figure 2 to change the overall ship model. The total regeneration time for a model of this size is 5 minutes after each change is made.

Changes can also be made to individual bulkhead sections and piping systems without an adverse effect on the other ship sections. This is shown in Figures 7 and 8 as the distance between bulkheads 2 and 3 are changed, similar to Figures 3 and 4. As the bulkhead distance changes, the piping system within that bulkhead section changes accordingly.

The piping systems between individual bulkhead sections were modeled as separate piping runs and not connected to the piping runs of other bulkhead sections. This was necessary due to regeneration errors that occurred when the piping system was designed as a continuous system between bulkhead sections. The errors were caused when different parts of the piping run were referenced to points of separate bulkhead sections. As changes were made to one bulkhead section, the locations of the

parametric points defining the piping run would be recalculated to reflect the change. As with any computer system, small mathematical differences occurred in calculating the dimensions of adjoining bulkhead sections and the related parametric points. These small differences, although not visibly noticeable, slightly altered the path of the piping runs between bulkhead sections to the point that certain piping components did not line up (especially bends and tees). The software would then disconnect the piping runs at these components. By splitting the piping runs at the bulkheads, all parametric points defining an individual run would be referenced to only one set of bulkhead dimensions, thus eliminating discrepancies and regeneration errors. This allows the piping system of one bulkhead section to be modified without altering the piping systems of other bulkhead sections. Changes can be made to these individual piping runs including addition or subtraction of components. Figure 9 displays a change made to the piping run made between bulkheads 1 and 2. Any modification can be taken out to get back to the original value.

The CAD model can be rotated to be viewed in different orientations. This rotation allows the various parts of the model to be viewed in relation to each other, for example, where the pipe runs and pumps are in relation to the decks of the ship. Figures 10, 11, and 12 show the forward part of the ship and piping model in the top, side, and front views, respectively.

The output of the Ship Parametric Modeling Program is several ASCII files containing the needed component characteristics of the modeled piping system. The first of these ASCII files contains the X, Y, and Z locations of the pipe and components relative to the

model's base coordinate system. Another ASCII file contains component name and nominal pipe diameter at beginning and end of the component run. Appendix B is the ASCII files output of the piping run between bulkheads 1 and 2. The information from these ASCII files, which can be input into BASIC, FORTRAN, or C programs as well as spreadsheet and database programs like Lotus 1-2-3 and dBASE III Plus, will be used in the Benefit Analysis Model program to obtain system-wide characteristics of the modeled piping system.

FUTURE WORK

The next step in the automated ship auxiliary systems design process will be to develop the Benefit Analysis Model. This development process will include adapting the output of the Ship Parametric Modeling Program for use in the Benefit Analysis Model, and determining the algorithms and programs necessary to calculate the desired system characteristics. Once the automated design process is successfully demonstrated for the DDG-51 and distributed fire main system models, 6.3 advanced development programs are planned to compare alternative design concepts for auxiliary systems on U.S. Navy combatants.

CONCLUSIONS

An automated design process is being developed to compare different auxiliary system concepts and select the best possible system configuration for a surface combatant. The distributed fire main system was selected as a sample advanced system concept to illustrate the automated modeling process. Parametric models representing the DDG-51 and the distributed fire main system were created in the Ship

Parametric Modeling Program. The ship and piping models were related with mathematical equations to the ship's overall length, width, and height. As different values were given to these controlling parameters, the ship and piping models changed accordingly. A change could also be made to an individual mathematical equation to alter one part of the ship or piping system. A list of the piping systems component characteristics can then be output to several ASCII files for inclusion in the Benefits Analysis Model to calculate system-wide characteristics.

FIGURES

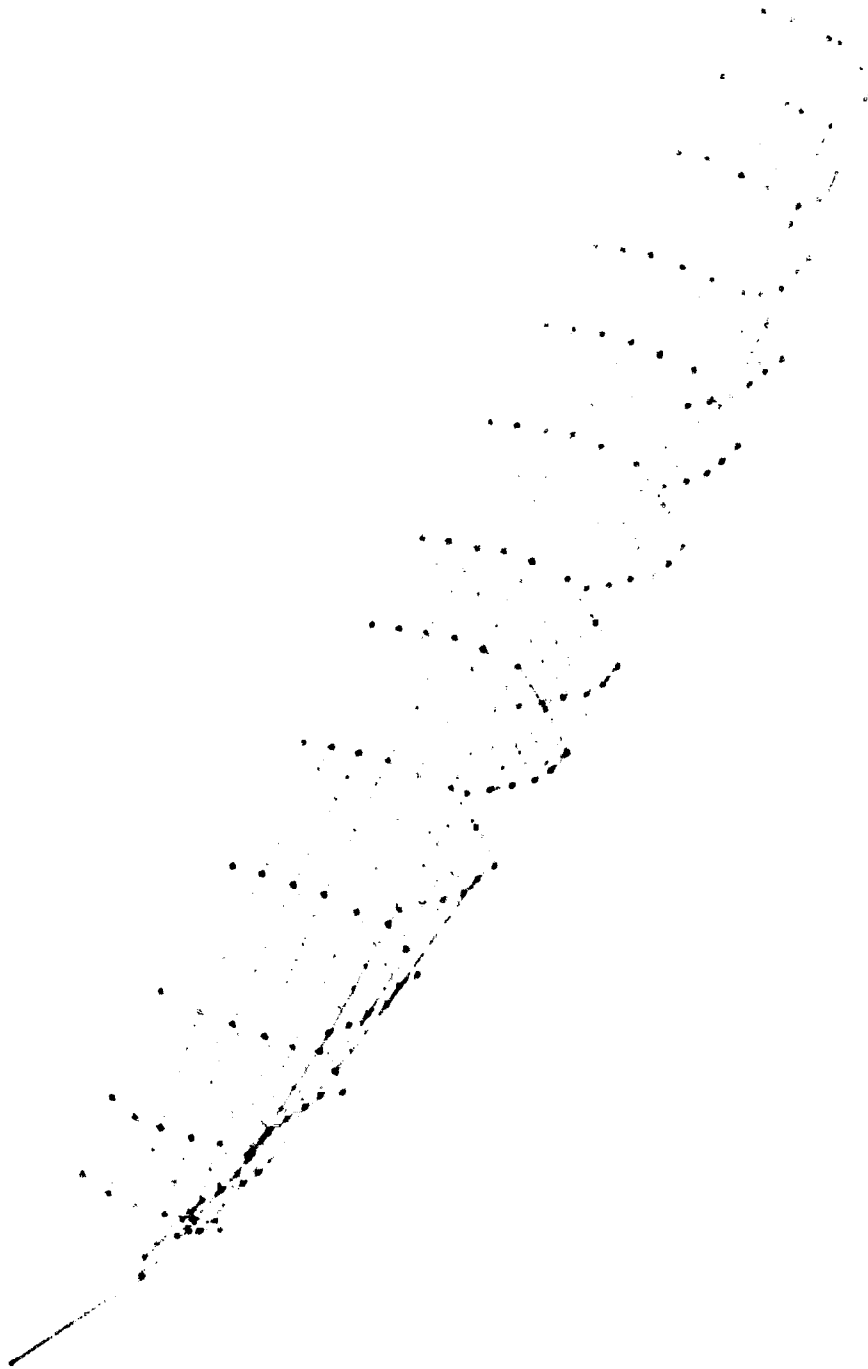


Fig. 1. Ship wireframe model with original dimensions of 505 ft length, 66 ft width, and 36 ft height.



Fig. 2. Ship wireframe model with new dimensions of 400 ft length, 100 ft width, and 50 ft height.



Fig. 3. Ship wireframe model with distance between bulkheads 2 and 3 of 36 ft.

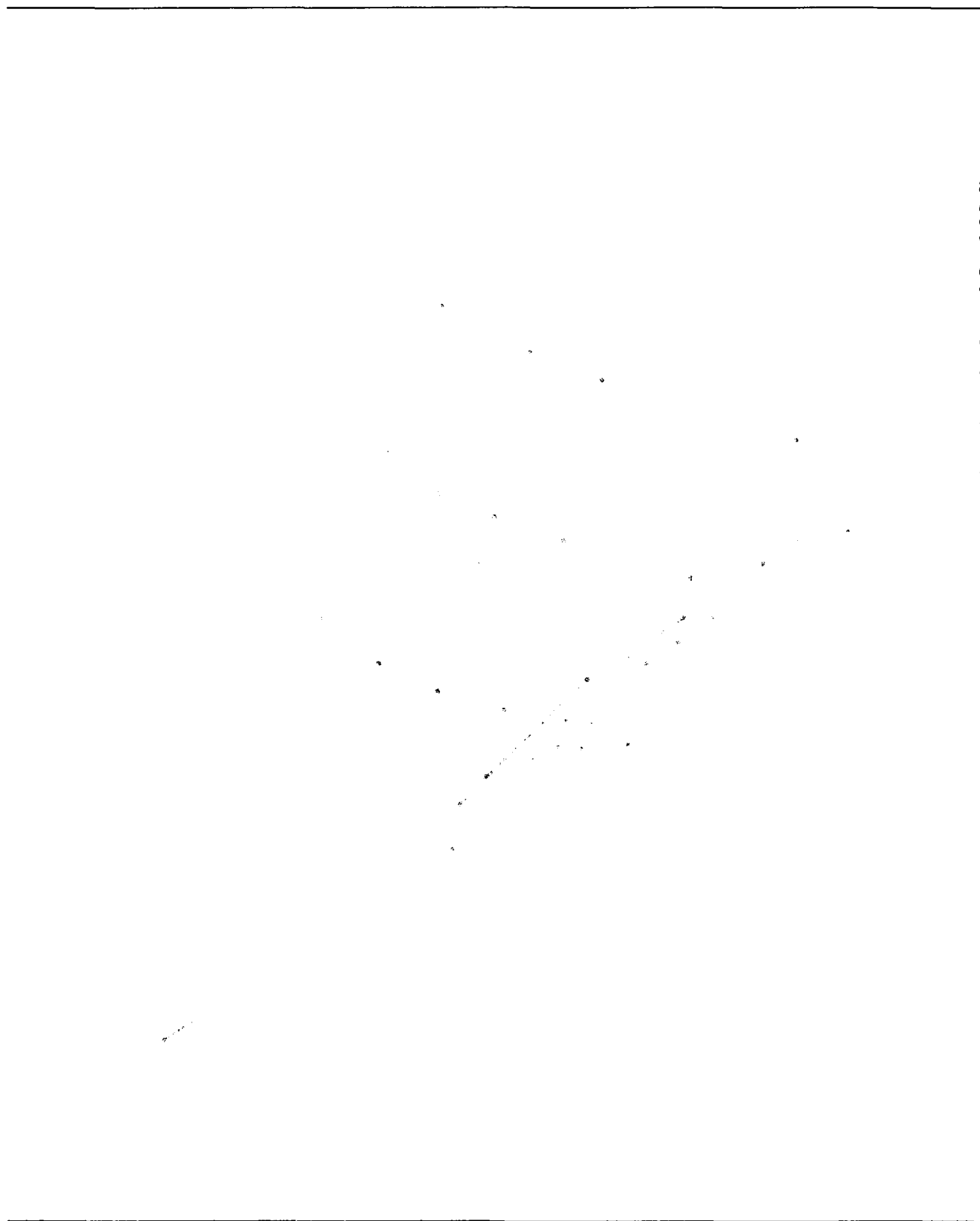


Fig. 4. Ship wireframe model with distance between bulkheads 2 and 3 of 20 ft.

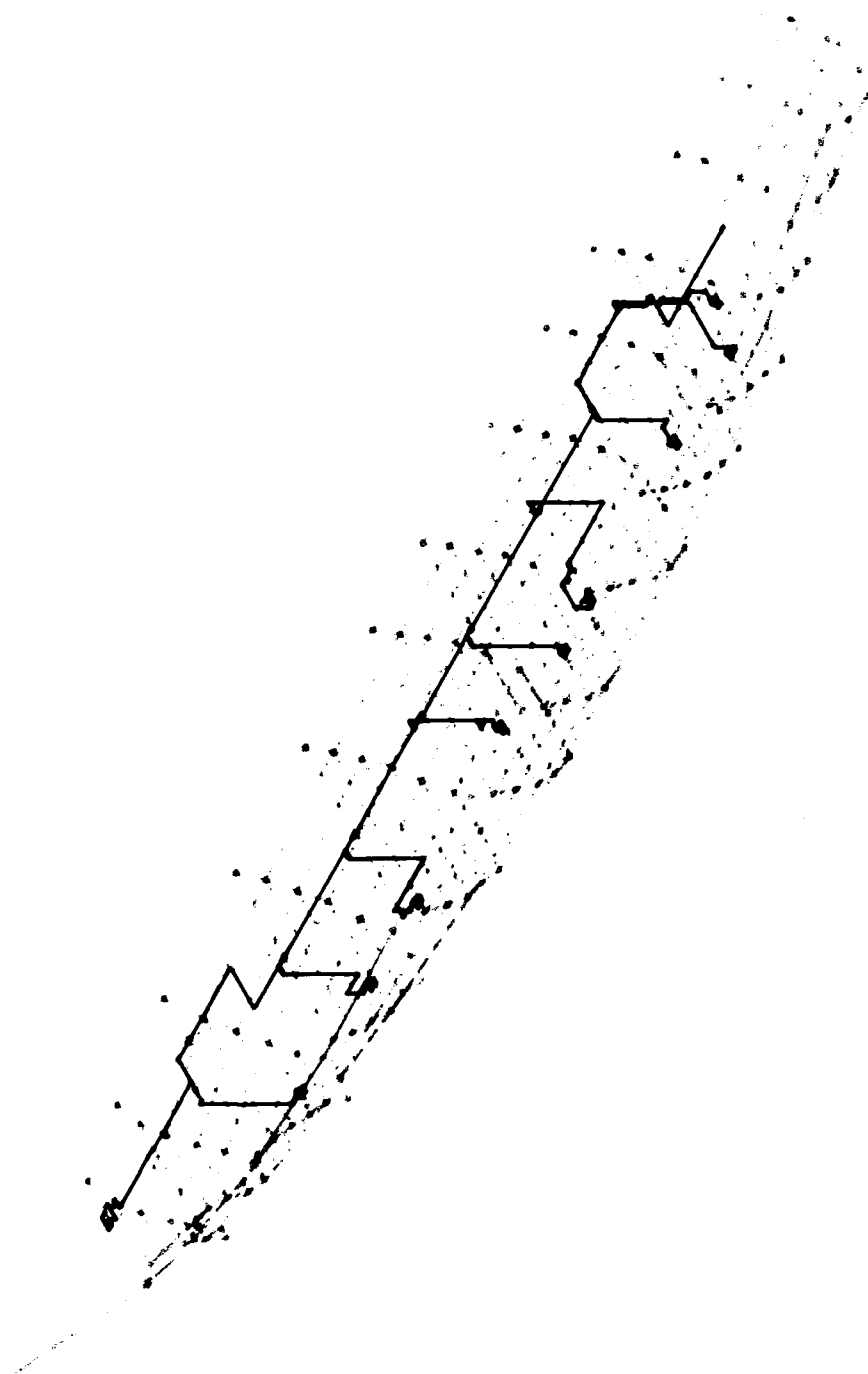


Fig. 5. Ship and piping model with original dimensions of 505 ft length, 66 ft width, and 36 ft height.

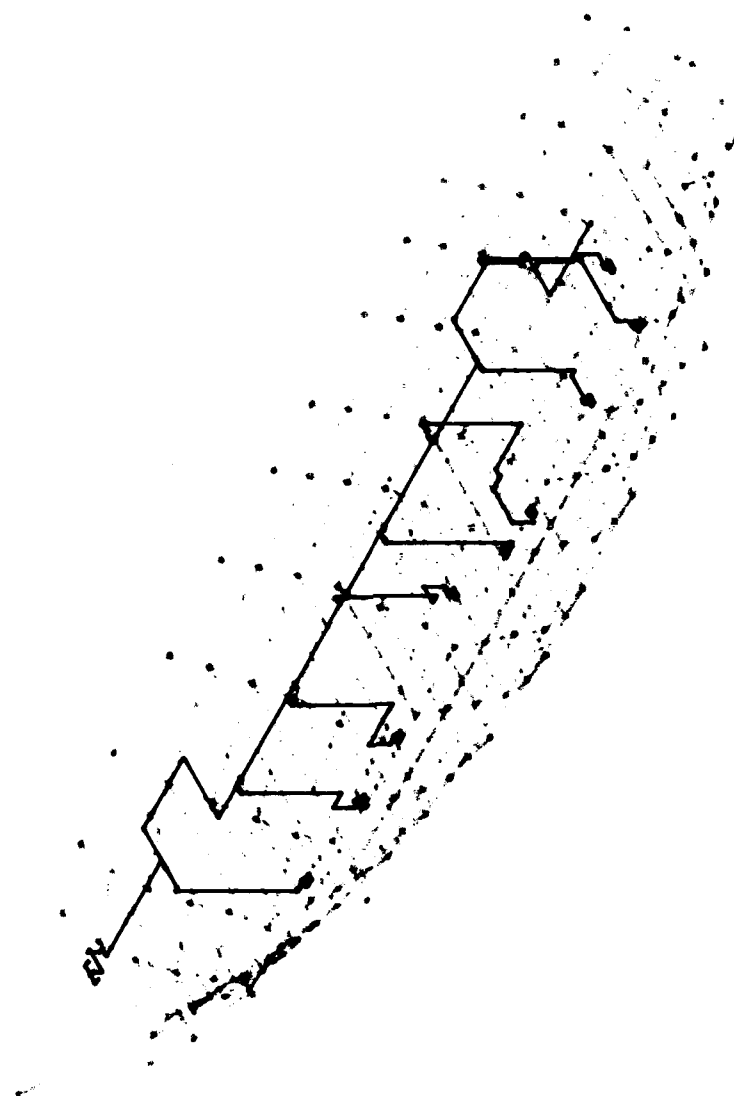


Fig. 6. Ship and piping model with new dimensions of 400 ft length, 100 ft width, and 50 ft height.

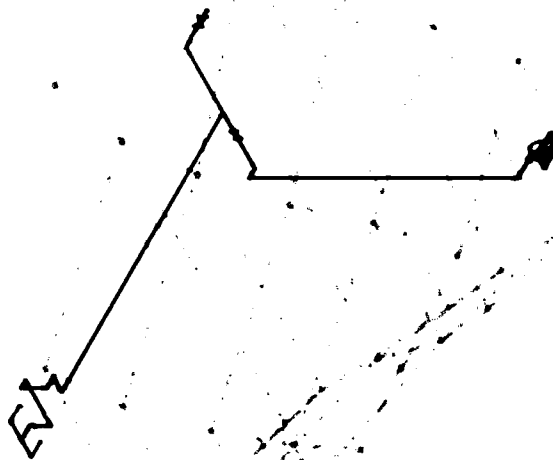


Fig. 7. Ship and piping model with distance between bulkheads 2 and 3 of 36 ft.

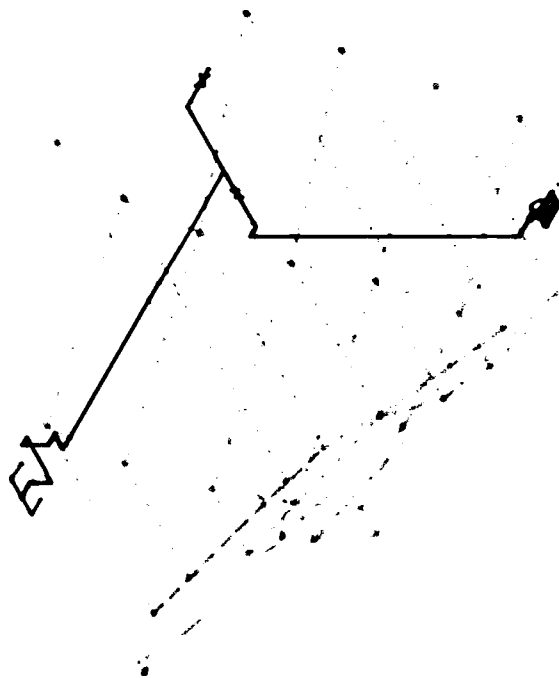


Fig. 8. Ship and piping model with distance between bulkheads 2 and 3 of 20 ft.

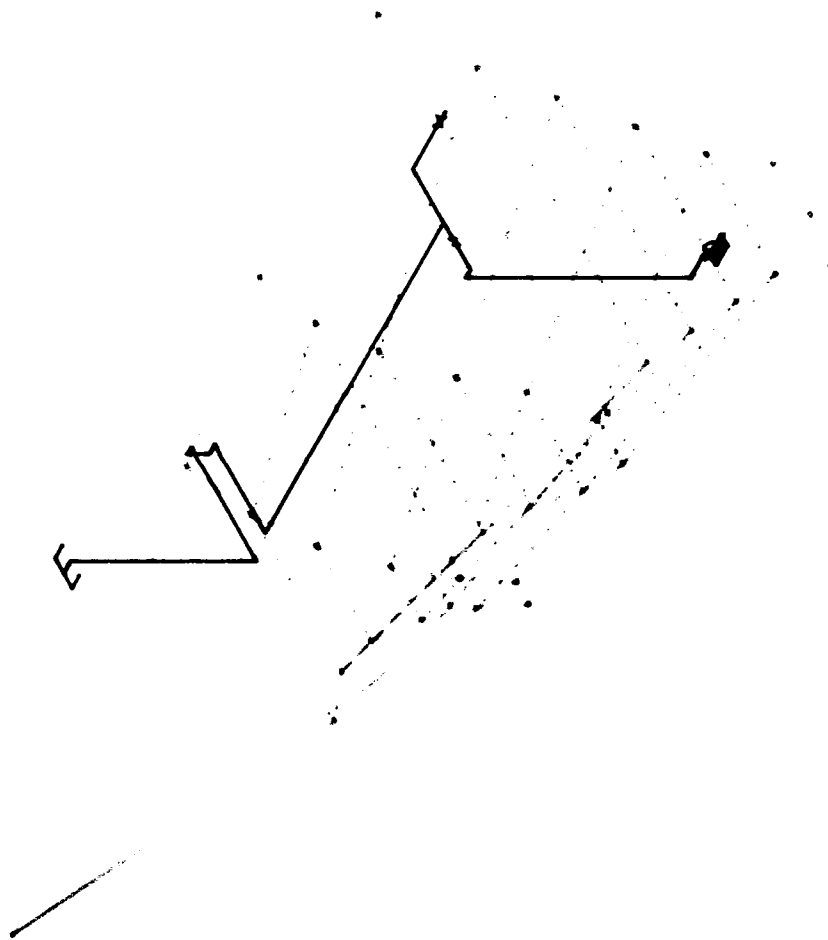


Fig. 9. Change in piping run between bulkheads 1 and 2.

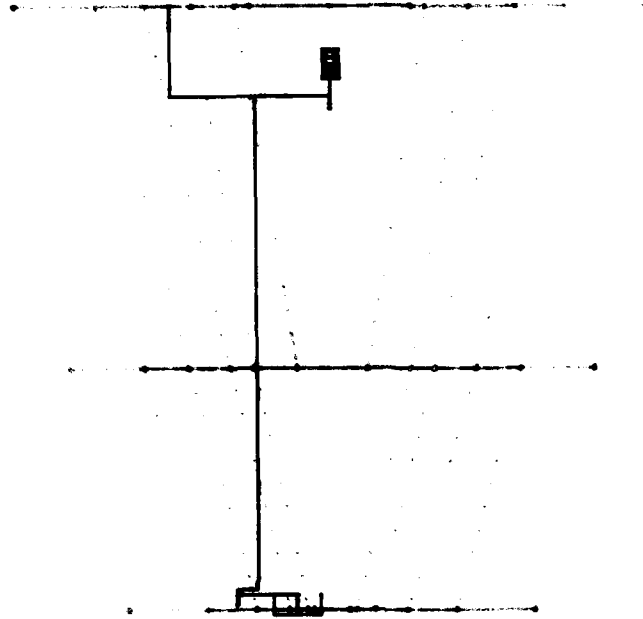


Fig. 10. Top view of ship and piping model.

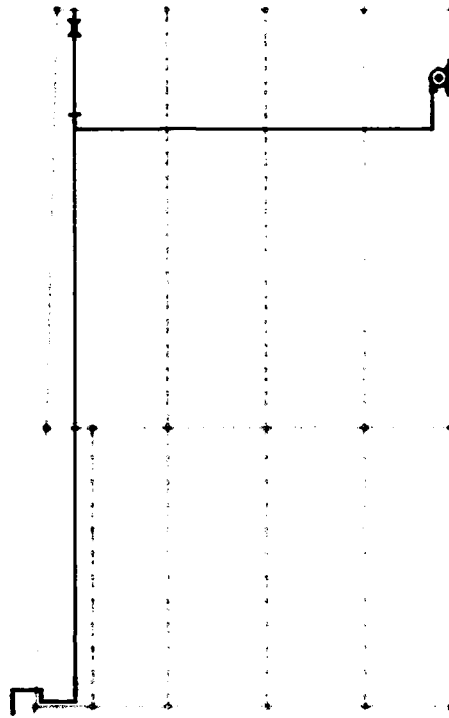


Fig. 11. Side view of ship and piping model.

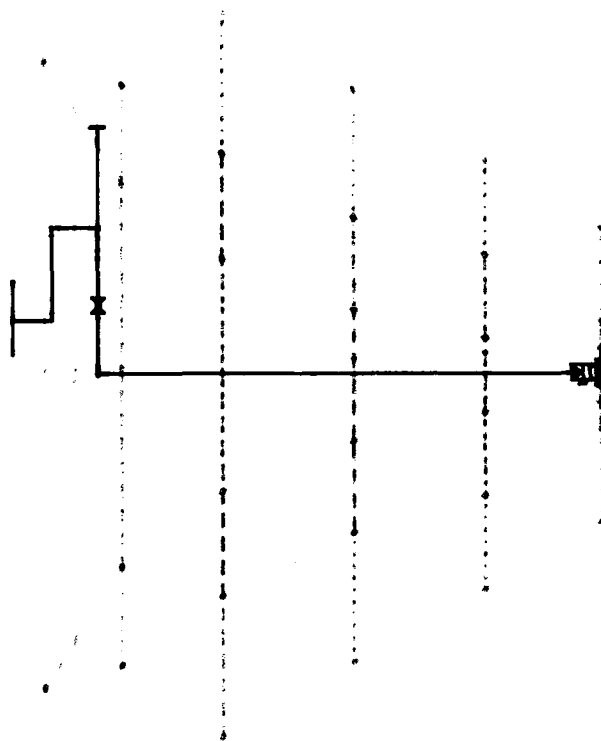


Fig. 12. Front view of ship and piping model.

APPENDIX A

EQUATIONS FOR PARAMETRIC POINTS OF SHIP AND PIPING MODELS

APPENDIX A

EQUATIONS FOR PARAMETRIC POINTS OF SHIP AND PIPING MODELS

The following list is a representation of the mathematical equations that define the parametric points used to create the ship and piping system models in the Ship Parametric Modeling Program. The numbers in parentheses following the equations show the calculated values used for the points locations (in inches).

length = 505.53×12 [6066.36]
width = 66×12 [792]
height = 36×12 [432]
sec01xlength = length/9.3616667 [648]
sec01ylength = -width/3.2592593 [-243]
sec01zlength = -height/5.1428571 [-84]
pt1by = width/1.6296296 [486]
pt1cy = width/8.4076433 [94.2]
pt1cz = -height/7.2 [-60]
pt1dy = width/2.0214395 [391.8]
pt1dz = -height/7.2 [-60]
pt1ey = width/5.1764706 [153]
pt1ez = -height/3.1304348 [-138]
pt1fy = width/2.3783784 [333]
pt1fz = -height/3.1304348 [-138]
pt1gy = width/4.125 [192]
pt1gz = -height/1.8 [-240]
pt1hy = width/2.6938776 [294]
pt1hz = -height/1.8 [-240]
pt1iy = width/3.697479 [214.2]
pt1iz = -height/1.2631579 [-342]
pt1jy = width/2.9139073 [271.8]
pt1jz = -height/1.2631579 [-342]
pt1ky = width/3.5675676 [222]
pt1kz = -height [-432]
pt1ly = width/3 [264]
pt1lz = -height [-432]
sec12xlength = length/21.06375 [288]
sec12ylength = -width/11.282051 [-70.2]
sec12zlength = -height/36 [-12]
pt2by = width/1.2643678 [626.4]
pt2cy = width/8.9795918 [88.2]
pt2cz = -height/9 [-48]
pt2dy = width/1.4715719 [538.2]

APPENDIX B
ASCII OUTPUT FOR PIPING RUNS BETWEEN BULKHEADS 1 AND 2

Design file data sorted by topo


Name	Occ	cp #	X	Y	Z	Node	Direct	Section	Flags	Topo	Seq Branch	Sg_occ	
PIPE	2	1	666.00	15.00	-60.00	-1	1	1	5	1	0	0	2
PIPE	2	2	645.00	15.00	-60.00	1	1	1	5	1	1	0	2
COMP	1	1	645.00	15.00	-60.00	1	1	1	3	1	2	0	1
COMP	1	2	642.00	18.00	-60.00	2	2	1	3	1	3	0	1
PIPE	4	1	642.00	18.00	-60.00	2	2	1	5	1	4	0	4
PIPE	4	2	642.00	39.50	-60.00	4	2	1	5	1	5	0	4
COMP	3	2	642.00	39.50	-60.00	4	2	1	3	1	6	0	3
COMP	3	1	642.00	44.50	-60.00	3	2	1	3	1	7	0	3
PIPE	8	1	642.00	44.50	-60.00	3	2	1	5	1	8	0	8
PIPE	8	2	642.00	69.00	-60.00	9	2	1	5	1	9	0	8
COMP	7	1	642.00	69.00	-60.00	9	2	1	3	1	10	0	7
COMP	7	2	645.00	72.00	-60.00	10	5	1	3	1	11	0	7
PIPE	9	1	645.00	72.00	-60.00	10	5	1	3	1	12	0	9
PIPE	9	2	666.00	72.00	-60.00	-1	5	1	5	1	13	0	9
COMP	3	3	644.50	42.00	-60.00	5	3	1	3	2	1	0	3
COMP	10	2	644.50	42.00	-60.00	5	3	1	3	2	2	0	10
COMP	10	1	648.50	42.00	-60.00	8	3	1	3	2	3	0	10
PIPE	6	1	648.50	42.00	-60.00	8	3	1	5	2	4	0	6
PIPE	6	2	660.00	42.00	-60.00	6	3	1	5	2	5	0	6
COMP	5	1	660.00	42.00	-60.00	6	3	1	3	2	6	0	5
COMP	5	2	666.00	42.00	-66.00	7	4	1	3	2	7	0	5
PIPE	12	1	666.00	42.00	-66.00	7	4	1	5	2	8	0	12
PIPE	12	2	666.00	42.00	-84.00	11	4	1	5	2	9	0	12
COMP	11	1	666.00	42.00	-84.00	11	4	1	3	2	10	0	11
COMP	11	2	666.00	48.00	-90.00	12	6	1	3	2	11	0	11
PIPE	20	1	666.00	48.00	-90.00	12	6	1	5	2	12	0	20
PIPE	20	2	666.00	108.00	-90.00	13	6	1	5	2	13	0	20
COMP	13	1	666.00	108.00	-90.00	13	6	1	3	2	14	0	13
COMP	13	2	660.00	114.00	-90.00	14	7	1	3	2	15	0	13
COMP	14	1	660.00	114.00	-90.00	14	7	1	3	2	16	0	14
COMP	14	2	654.00	114.00	-96.00	15	8	1	3	2	17	0	14
PIPE	21	1	654.00	114.00	-96.00	15	8	1	5	2	18	0	21
PIPE	21	2	654.00	114.00	-120.00	16	8	1	5	2	19	0	21
COMP	15	1	654.00	114.00	-120.00	16	8	1	3	2	20	0	15
COMP	15	2	660.00	114.00	-126.00	17	9	1	3	2	21	0	15
PIPE	17	1	660.00	114.00	-126.00	17	9	1	5	2	22	0	17
PIPE	17	2	666.00	114.00	-126.00	18	9	1	5	2	23	0	17
COMP	16	1	666.00	114.00	-126.00	18	9	1	3	2	24	0	16
COMP	16	2	672.00	108.00	-126.00	19	10	1	3	2	25	0	16
PIPE	22	1	672.00	108.00	-126.00	19	10	1	5	2	26	0	22
PIPE	22	2	672.00	96.00	-126.00	20	10	1	5	2	27	0	22
COMP	18	1	672.00	96.00	-126.00	20	10	1	3	2	28	0	18
COMP	18	2	678.00	90.00	-126.00	21	11	1	3	2	29	0	18
PIPE	19	1	678.00	90.00	-126.00	21	11	1	5	2	30	0	19
PIPE	19	2	936.00	90.00	-126.00	-1	11	1	5	2	31	0	19

Seq	Block	Occ	Name	NPS1	NPS2	Sch1	Sch2	
PIPESEQ1	N1	2	PIPE100142D100	PIPE 2.0"	2.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	1	90E39264D	90E 2.0"	2.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	4	EL90	PIPE 2.0"	2.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	3	TEE	TEE 2.0"	2.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	10	CONRED	CONRED 4.0"	2.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	6	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	5	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	12	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	11	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	20	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	13	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	14	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	21	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	15	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	17	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	16	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	22	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	18	90E39264D	90E 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	19	PIPE100142D100	PIPE 4.0"	4.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	8	PIPE100142D100	PIPE 2.0"	2.0"	BE	S-STD S-STD 0	0
COMPSEQ1	N1	7	90E39264D	90E 2.0"	2.0"	BE	S-STD S-STD 0	0
PIPESEQ1	N1	9	PIPE100142D100	PIPE 2.0"	2.0"	BE	S-STD S-STD 0	0

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